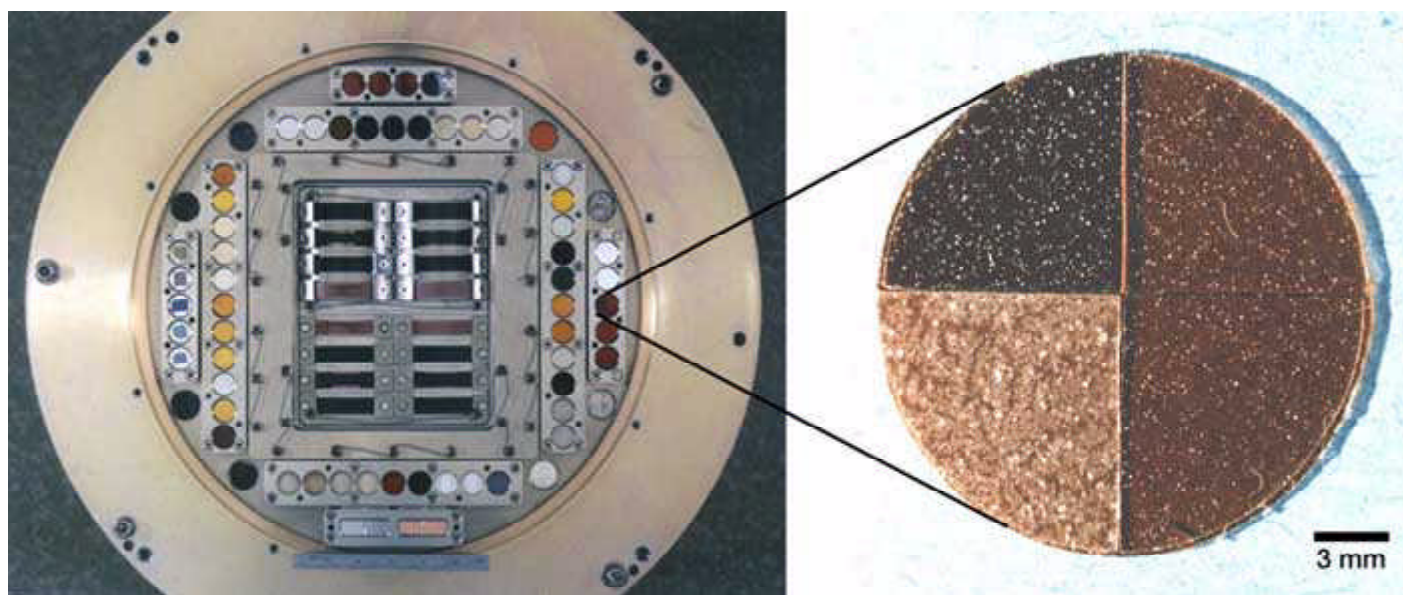


Sensitive Technique Developed Using Atomic Force Microscopy to Measure the Low-Earth-Orbit Atomic Oxygen Erosion of Polymers

A recession measurement technique has been developed at the NASA Glenn Research Center to determine the atomic oxygen durability of polymers exposed to the space environment for short durations. Polymers such as polyimide Kapton and Teflon FEP (fluorinated ethylene propylene, DuPont) are commonly used in spacecraft because of their desirable properties, such as flexibility, low density, and in the case of FEP, low solar absorptance and high thermal emittance. Polymers on the exterior of spacecraft in the low-Earth-orbit environment are exposed to energetic atomic oxygen, resulting in erosion and potential structural loss. It is, therefore, important to understand the atomic oxygen erosion yield (E , the volume loss per incident oxygen atom) of polymers being considered in spacecraft design. Because long-term space exposure data are rare and very costly, short-term exposures, such as on the space shuttles, are often relied on for atomic oxygen erosion determination. The most common technique for determining E is through mass-loss measurements. For limited-duration exposure experiments, such as shuttle flight experiments, the atomic oxygen fluence is often so small that mass-loss measurements are not sensitive enough. Therefore, a recession measurement technique has been developed at Glenn to obtain accurate erosion yields of polymers exposed to low atomic oxygen fluences.



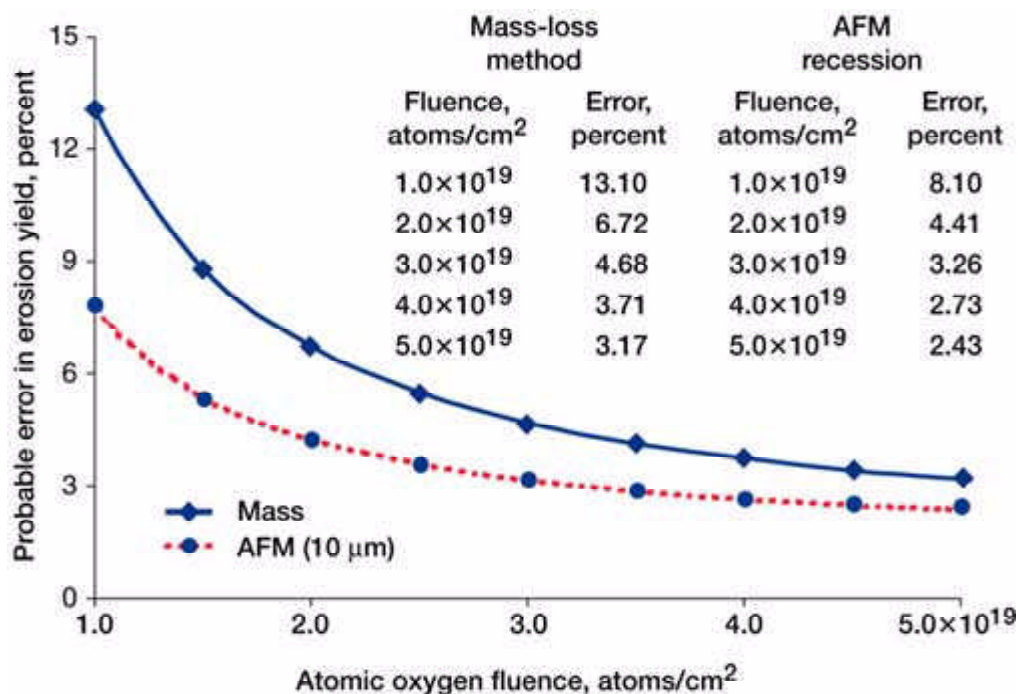
Example of a salt-sprayed, multiple-polymer flight sample prepared and flown for characterization using the AFM recession technique. This photograph shows the Limited Duration Candidate Exposure (LDCE-4) flight hardware and polymer sample prior to

flight aboard the shuttle during STS-51.

The technique developed at Glenn is based on recession measurements. It uses the selective protection of polymer samples with intimate contact particles, combined with postflight atomic force microscopy (AFM) analysis of recession, or erosion depths, to obtain accurate erosion yields. Two methods of protection have been proposed, salt spraying and mica dusting. Specific procedures and characterization issues have been studied at Glenn with collaborative help from Hathaway Brown School for girls and Manchester College. These issues include salt spraying, salt crystal variations, potential problems with salt-rings and condensation, and mica-dusting issues. Also studied were the specific atomic force microscope (AFM) procedures necessary for this technique. For example, a salt-sprayed sample flown as part of the Limited Duration Candidate Exposure (LDCE-4) shuttle flight experiment on STS-51 was used to study the use of contact-versus noncontact-mode imaging for determining erosion depth measurements. Analyses indicate that contact-mode measurements can be used for erosion depth measurement without significantly degrading the samples.

This AFM recession technique has the advantage that very small sample areas can be used to obtain erosion yield data, and multiple polymers can be put together as one flight sample. Error analyses were computed for this technique and for the traditional erosion yield determination technique based on mass loss, and both were highly dependent on the atomic oxygen fluence as expected. The recession technique was found to be very dependent on the protective particle height in addition to the atomic oxygen fluence, and it was found to be more accurate than the mass-loss technique for protective particles less than 17 μm thick. For example, for a fluence of 1310^{19} atoms/ cm^2 , the probable error in the atomic oxygen erosion yield for the AFM recession technique (using a 10- μm -thick protective particle) is approximately 60 percent of the mass loss uncertainty (7.7 versus 13.1 percent, respectively).

Glenn researchers plan to use this AFM recession depth technique to determine the erosion yield of 42 different polymers in the shuttle flight experiment Polymer Erosion and Contamination Experiment (PEACE) a collaborative experiment between Glenn and Hathaway Brown School potentially to be flown in 2002 or 2003. As part of PEACE, identical polymers will be flown and their erosion yields determined using the mass-loss technique, so a direct comparison between these two erosion yield techniques will be made.



Comparison of the percent probable error in the atomic oxygen erosion yields as a function of atomic oxygen fluence for the mass loss and AFM recession (10-mm particle height) techniques for low atomic oxygen fluences.

Long description

Graph shows data for mass-loss method and AFM recession for fluences (in atoms per cm²) of 1.0., 2.0, 3.0, 4.0, and 5.0×10¹⁹. For the smallest to the largest fluences, respectively, the percent error for the mass-loss method is 13.10, 6.72, 4.68, 3.71, and 3.17; and for AFM recession is 8.10, 4.41, 3.26, 2.73, and 2.43.

Find out more about this research:

Glenn's Electro-Physics Branch <http://www.grc.nasa.gov/WWW/epbranch/ephhome.htm>

Hathaway Brown's PEACE information

<http://www.hb.edu/school/upper/spotlight/srp/peace/default.htm>

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